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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

REMOTE-SENSING STUDIES OF HYDROLOGIC ENVIRONMENTS IN THE LOWER RARITAN RIVER SYSTEM, NEW JERSEY

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OPEN-FILE REPORT
1973

(NASA-CR-138398) REMOTE-SENSING STUDIES OF HYDROLOGIC ENVIRONMENTS IN THE LOWER RARITAN RIVER SYSTEM, NEW JERSEY (Geological Survey, Reston, Va.) ~~16~~ 20 p HC $4.00 CSCL 08H

N74-22972
Unclas
G3/13 38953

Prepared in cooperation
with the National Aeronautics
and Space Administration

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ABSTRACT

The U.S. Geological Survey, in cooperation with the National Aeronautics and Space Administration, conducted a series of remote-sensing experiments (Missions 65 and 82) in the lower Raritan River system (Test Site 161) in east-central New Jersey in January and November 1968. The airborne multisensor missions included photographic and thermal-infrared sensors operated over a single site at a time when streamflow and water-temperature observations were being made on the ground. Remote-sensing data showed (1) effect of thermal waste-water discharges on stream temperatures, (2) cross-channel variations in thermal characteristics due to waste-water discharge, channel characteristics, and tidal currents, (3) influence of flow rates on dispersion, (4) patterns and distribution of ice cover, and (5) movement of sediment loads.

INTRODUCTION

The U.S. Geological Survey, in cooperation with the National Aeronautics and Space Administration (NASA), is seeking to determine and to define applications of remote-sensing technology to hydrologic investigations, such as studies of the character and magnitude of water resources, the location and distribution of these resources, and the principles and processes involved. This report is the result of investigations in the lower Raritan River in New Jersey (NASA Test Site 161). Data upon which this report is based were obtained by NASA on the following flights: Mission 65, January 18, 1968 (Bratton, 1968); and Mission 82, November 6, 1968 (Eaton, 1969).

Remote-sensing techniques were used on these flights to collect two types of data: (1) aerial photographs, both color and color infrared (IR), and (2) thermal IR imagery.

NASA Test Site 161 is an area between Manville and Edison, N.J. that includes a 10-mile (16 km) reach of the lower Raritan River system (fig. 1) which flows through a highly industrialized and urbanized area in east-central New Jersey. In the area of the test site, the Delaware and Raritan Canal is parallel to the river. Because of a bend of approximately 90 degrees in the river channel at Bound Brook, two flight lines were used.

Remote-sensing data were gathered primarily to determine the presence, distribution, and movement of waste-water discharges in this reach of the Raritan River. Information also was obtained on patterns and distribution of ice cover and on the movement of suspended sediment.

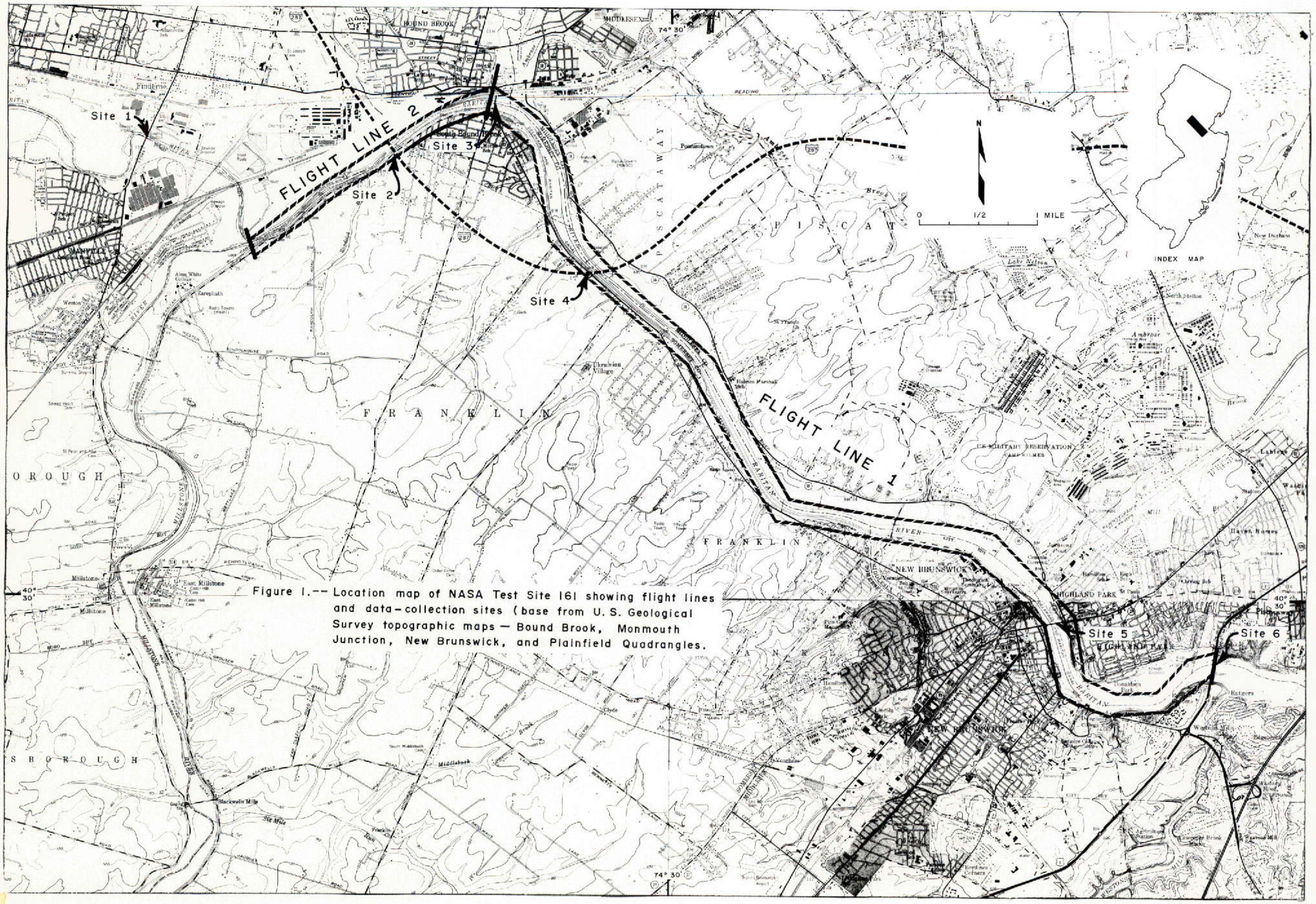


Figure 1.-- Location map of NASA Test Site 161 showing flight lines and data-collection sites (base from U. S. Geological Survey topographic maps — Bound Brook, Monmouth Junction, New Brunswick, and Plainfield Quadrangles.

DATA COLLECTION

Remote-sensing data were collected over the test site by NASA on two missions as part of its Earth Resources Aircraft Program. A summary tabulation of pertinent information concerning these two missions is given on table 1.

The atmosphere is a good absorber of IR energy, except in the 2-6 and 8-13 μm ranges. Thus, observations of the earth's surface are usually made through these two "windows." Because more energy is emitted in the 8-13 μm band, the thermal IR imagery was collected in that band during pre-dawn hours.

The general quality and resolution of all film positives were satisfactory for visual interpretation. In most cases, sufficient water and land areas were shown on the film data for orientation of ground-control points and imagery identification. However, the range of tonal density on the thermal imagery of water bodies was small when compared to the tonal range for terrestrial features. This probably is due to the relatively constant temperature and emissivity that existed at the surface of the water bodies.

Water-temperature data collected during this and previous investigations indicated cross-channel variations, due either to variations in the amount of decomposing organic materials or to inadequate mixing of thermal discharges in the river system. Results of water-quality investigations of the lower Raritan River system by Faust and others (1970) indicated the presence of high concentrations (7.4-210 μg/l) of phenolic compounds in the water and also cross-channel variations in the concentration of these compounds at several sampling points. Such compounds usually are associated with industrial waste-water discharges. The exothermic microbiological decomposition of these and other organic wastes in the river possibly result in a measurable increase in temperature.

Water-temperature measurements in the river cross section and profile and in the parallel canal are summarized in table 2. Although these data were obtained on the morning prior to the November 1968 NASA flight, they confirm the general pattern of increasing temperatures between Manville (site 1, fig. 1) and Bound Brook (site 3), primarily due to the concentration of waste-water effluents in this area, followed by a temperature decrease downstream from Bound Brook (U.S. Geological Survey and Water Quality Office, Environmental Protection Agency, unpublished data, 1968-69). Other field data collected during this and the previous flight are summarized on table 3.

Table 1.--Summary tabulation of information pertaining to remote-sensing data collected at NASA Test Site 161 during 1968.

Mission number	Date	Altitude above MSL (ft)	Approx. time (EST)	Sensor Data
65	01-18-68	1500	0415	TIR
		6000	1100	C, CIR, TIR
82	11-06-68	1500	0345	TIR

C Color photography
CIR Color infrared photography
TIR Thermal infrared imagery

Table 2.--Summary tabulation of stream-temperature measurements at selected sampling sites on the Raritan River and Delaware and Raritan Canal between Manville and Edison, N.J., November 5, 1968.

Location	Site no. (fig. 1)	Time (EST)	Water Temperature (°C) RS1/	RC	C	LC	LS
Raritan River							
Manville (Main St. bridge)	1	0730	17.0	9.5	9.5	9.9	9.9
Bound Brook-North (I-287 bridge-north crossing)	2	0700	11.0	11.2	12.2	12.5	12.9
Bound Brook-South (Queen's bridge)	3	0630	10.0	11.2	13.0	13.0	12.2
So. Bound Brook (I-287 bridge-south crossing)	4	0600	11.8	12.0	11.8	12.0	12.0
New Brunswick (Raritan Ave. bridge)	5	0530	11.4	11.4	11.2	11.6	11.8
Edison (U.S. Highway No. 1 bridge)	6	0500	11.2	11.4	11.1	11.6	12.0
D & R Canal							
Bound Brook-North (I-287 north)	2	0700	--	--	10.0	--	--
So. Bound Brook (I-287 south)	4	0600	--	--	10.9	--	--

Table 2.--Summary tabulation of stream-temperature measurements at selected sampling sites on the Raritan River and Delaware and Raritan Canal between Manville and Edison, N.J., November 5, 1968--Continued.

Location	Site no. (fig. 1)	Time (EST)	Water Temperature (°C) RS[1]	RC	C	LC	LS
D & R Canal--Continued							
New Brunswick (Raritan Ave. bridge)	5	0530	--	--	11.2	--	--

[1] RS = right side or south bank
RC = right center
C = center
LC = left center
LS = left side or north bank

Table 3.--Summary tabulation of streamflow measurements at selected sampling sites on the Raritan River, January 18 and November 6, 1968.

Location	Site no. (fig. 1)	Date	Time (EST)	Discharge (ft^3/s)
Manville	1	01-18-68	0200	959
			0400	917
			0600	877
		11-06-68	0200	159
			0400	159
			0600	159
Bound Brook - North	2	01-18-68	0200	1780
			0400	1690
			0600	1610
		11-06-68	0200	171
			0400	161
			0600	164

DISCUSSION

IR imagery collected in January 1968 (not shown) was obtained under cold-weather conditions. Spatial (longitudinal or lateral) thermal variations were not observed on the imagery of the river channel near or below known industrial discharges. This was originally thought by the authors to be due to lower ambient temperatures inhibiting the chemical and biochemical reaction systems. However, upon further analysis, a more feasible explanation for the absence of thermal plumes normally associated with waste discharges was derived. This explanation is described below.

On January 14, four days prior to the NASA flight, a fairly large storm of 1.0-1.5 in (25-38 mm) occurred in the basin. Mean daily discharges at the Bound Brook gaging station (fig. 1, site 2) peaked the next day at 7,010 ft^3/s (199 m^3/s) and receded to 3,880 ft^3/s (110 m^3/s) on the 16th, to 2,400 ft^3/s (68 m^3/s) on the 17th and 1,540 ft^3/s (44 m^3/s) on the 18th. Based on records dating from 1904, the 1,700 ft^3/s (48 m^3/s) discharge during the flight (table 3) can be expected to be equaled or exceeded at this gage only 17 percent of the time (Laskowski, 1970). Thus, any waste-water discharges entering the river system would be mixed almost immediately by the turbulence associated with the high flow rates.

Also, it might be speculated that the characteristic thermal plumes were not observed because of ice cover on the river. It seems unreasonable to expect an ice cover under such a high flow. The absence of such a cover was confirmed easily by inspection of color photography (table 1), which was collected 7 hours subsequent to that of the imagery.

An apparent ice cover (or lower water temperatures) in the tidal areas of the river below site 5 (fig. 1) and along much of the Delaware and Raritan Canal was noted on the image collected in January 1968. Inspection of the color photography taken later in the day confirmed this presence of ice cover. Also noted on this imagery and confirmed on the color photographs were breaks in the Canal's ice cover at four locks, due to higher velocities produced by channel constrictions that inhibited ice formation, and below Raritan Avenue bridge (site 5, fig. 1), due to tidal flows. Accumulation of ice floes in the tidal area below site 5 is a common occurrence under the conditions existing at the time of the NASA flight. High streamflow had broken the river's ice cover and washed it into the sluggish tidal area, where it accumulated. Studies of the color photographs obtained during this flight indicate that increases in salinity and warmer tidal waters facilitated the melting of the ice floes below site 6 (fig. 1).

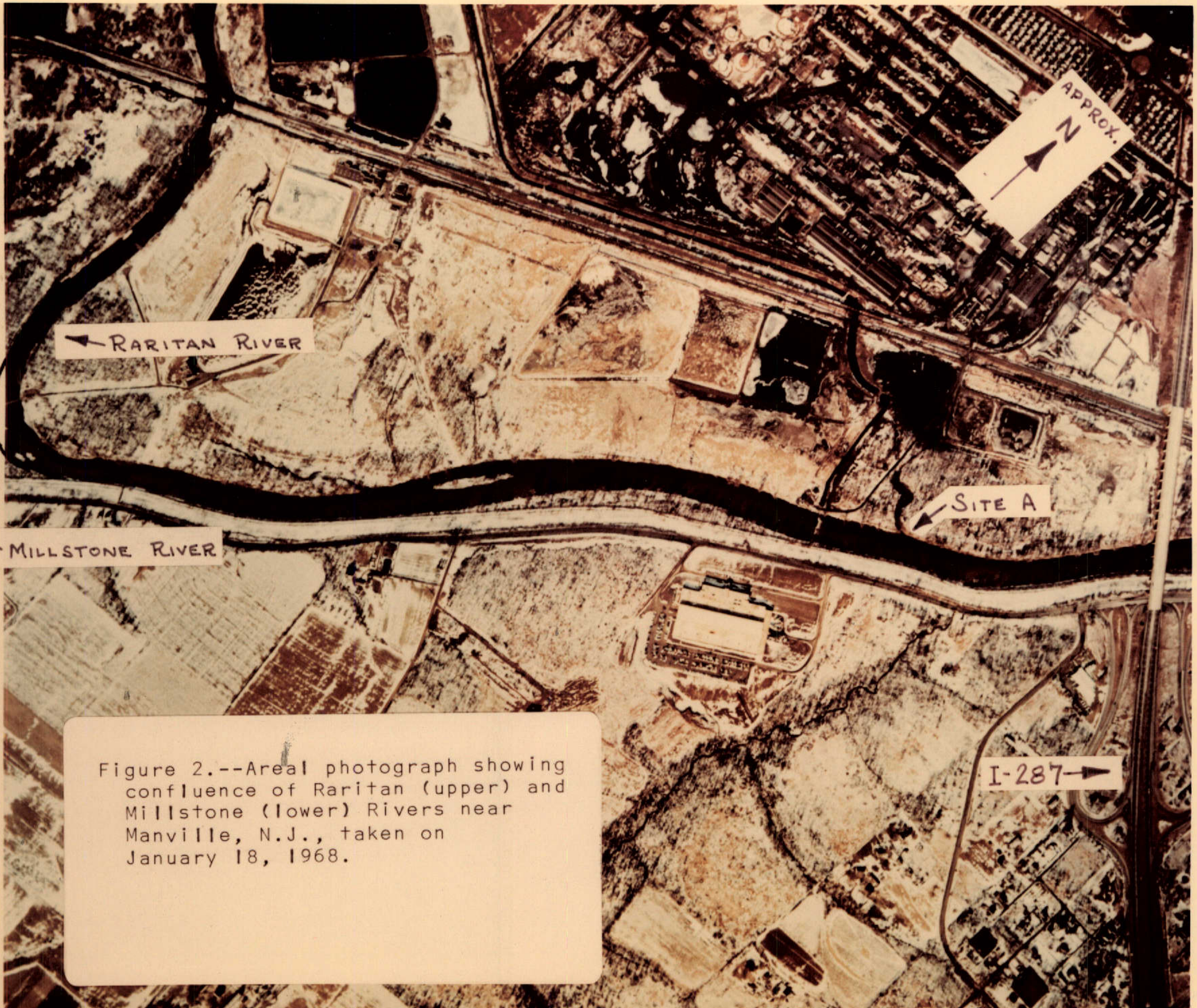


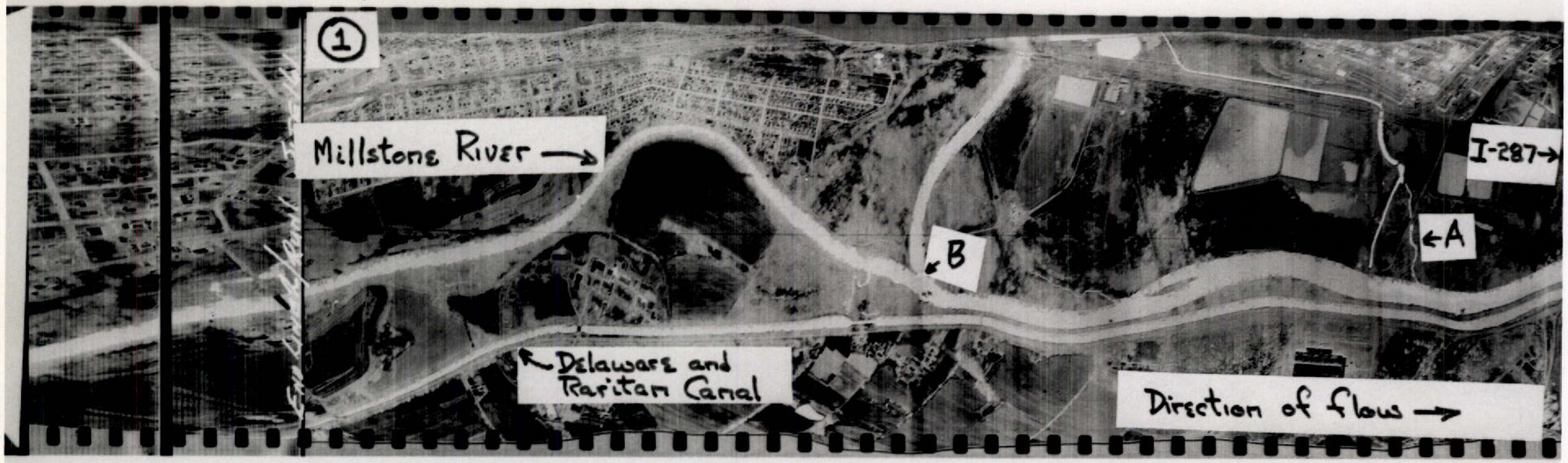
Figure 2.--Areal photograph showing confluence of Raritan (upper) and Millstone (lower) Rivers near Manville, N.J., taken on January 18, 1968.

Inspection of the color photographs showed clearly (fig. 2) that the Millstone River (about 250 ft^3/s (7.0 m^3/s) discharge at time of flight) was transporting higher concentrations (estimated from sediment-transport curve to be 75 mg/l) of sediment than that of the Raritan River (about 570 ft^3/s (16 m^3/s) at an estimated concentration of 40 mg/l). A cross-channel variation in sediment concentration, with higher concentrations along the south side of the river, was discernible for at least 3 miles (4.8 km) downstream from the confluence. Also, the industrial effluent (open channel) labelled A is extremely dark in color and entrains along the shore line at least to the I-287 bridge just downstream. This entrainment was not observed on the imagery collected on this date.

IR imagery collected on a NASA flight over this test site on November 6, 1968 is illustrated in figure 3. During this flight flows (table 3) were extremely low (expected to be equalled or exceeded 90 percent of the time). Also, weather conditions were good for maximum contrast between stream temperatures and waste-water temperatures, and for biochemical decomposition in the river to occur. Thus, this flight produced data ideal for detection of thermal distributions in the river system. Variations in the density of the emulsion on this imagery indicate several sources of industrial or municipal waste-water discharges (A to G). Of special interest are waste discharges from chemical plants at points A and C, and the resultant cross-channel thermal variations in the river water. Point B is the location of a municipal waste-treatment plant outfall.

Cross-channel variation in the temperature (or emissivity) of the waste-water discharge at point A is observed readily on the thermal imagery. Field measurements (table 2) collected the previous morning at site 2 (fig. 1) just below point A showed an increase in water temperatures from right (southern) to left (northern) bank. The effluents from this industrial-treatment plant are split into two parts. One, the downstream part, is discharged directly into the river and seems to entrain along the northern shore line. The upstream part is passed into a pipe laid in a small weir. The function of this pipe is to disperse the waste load equally across the river channel. However, the thermal imagery indicates that the discharge from the pipe extends across only half of the river. The full use of this pipe was restored in 1970 by the industry.

Cross-channel variations are discernable also in the river near point C. Field data (table 2) collected at the bridge (site 4) just below point C indicates only slightly higher temperatures on the left (northern) bank. The small dam (Fieldsville Dam), which has a spillway for low flows on the right (southern) bank, provides adequate mixing. Note that this dam (H) can be seen on this image, but was inundated by higher flows on the earlier image (not shown).



FLIGHT LINE 2

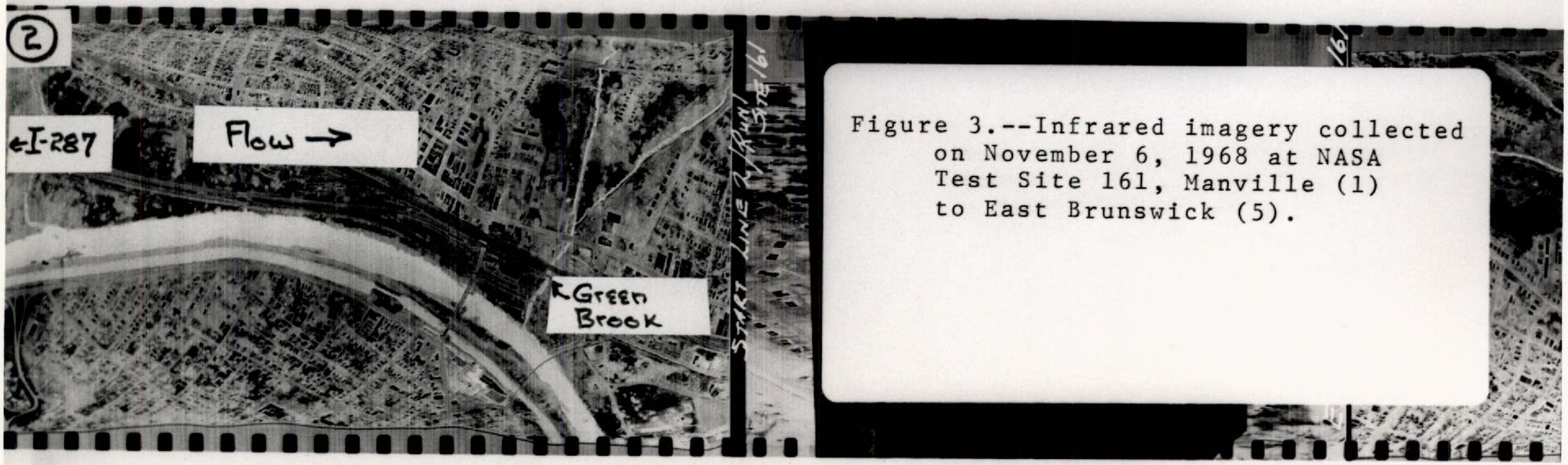
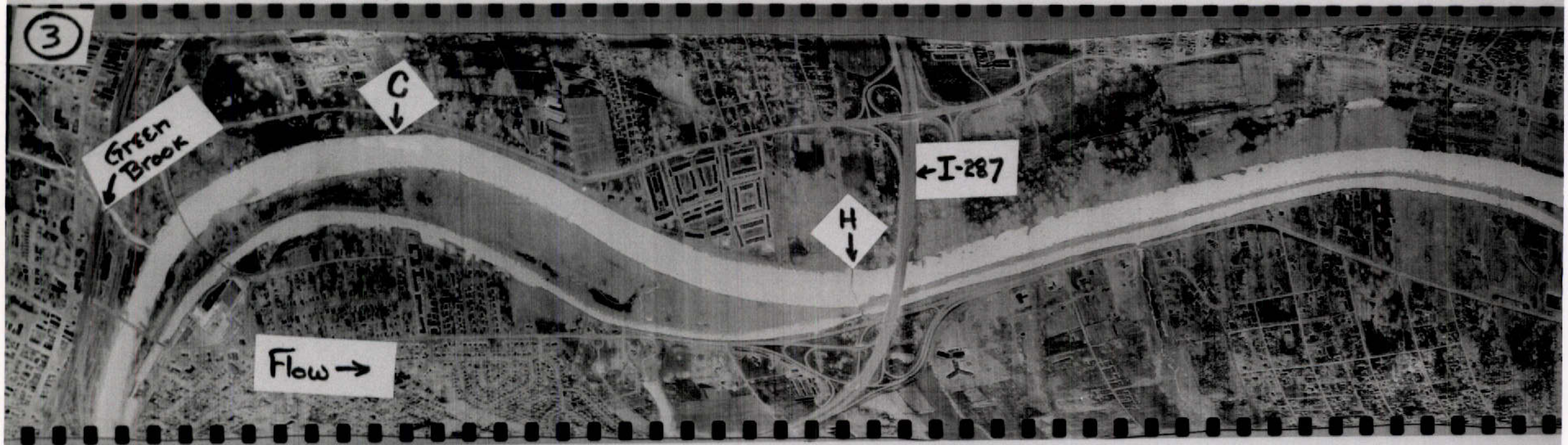
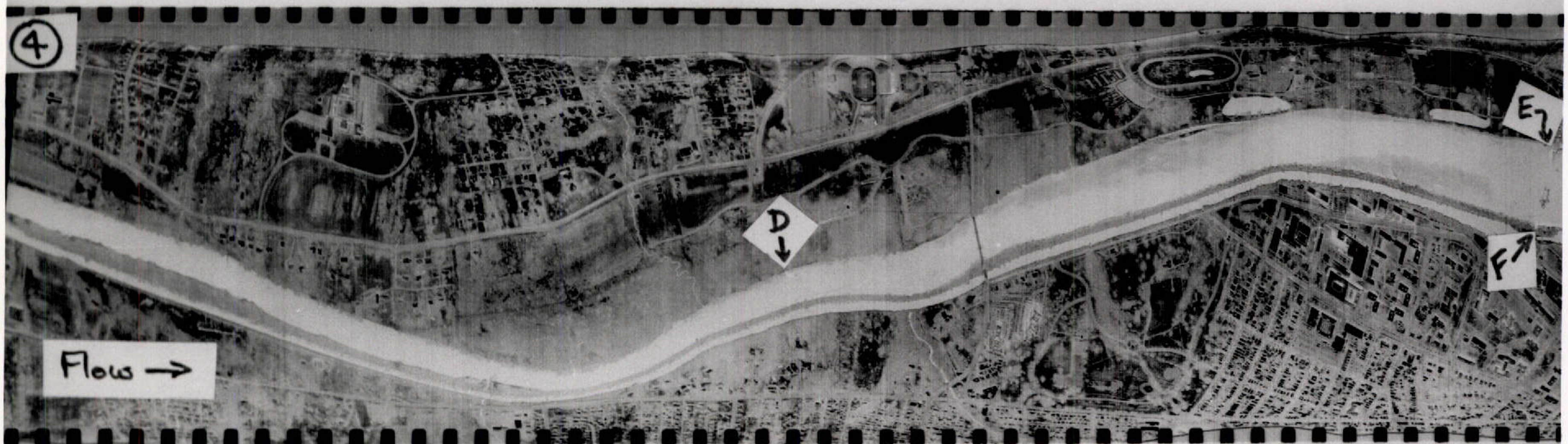


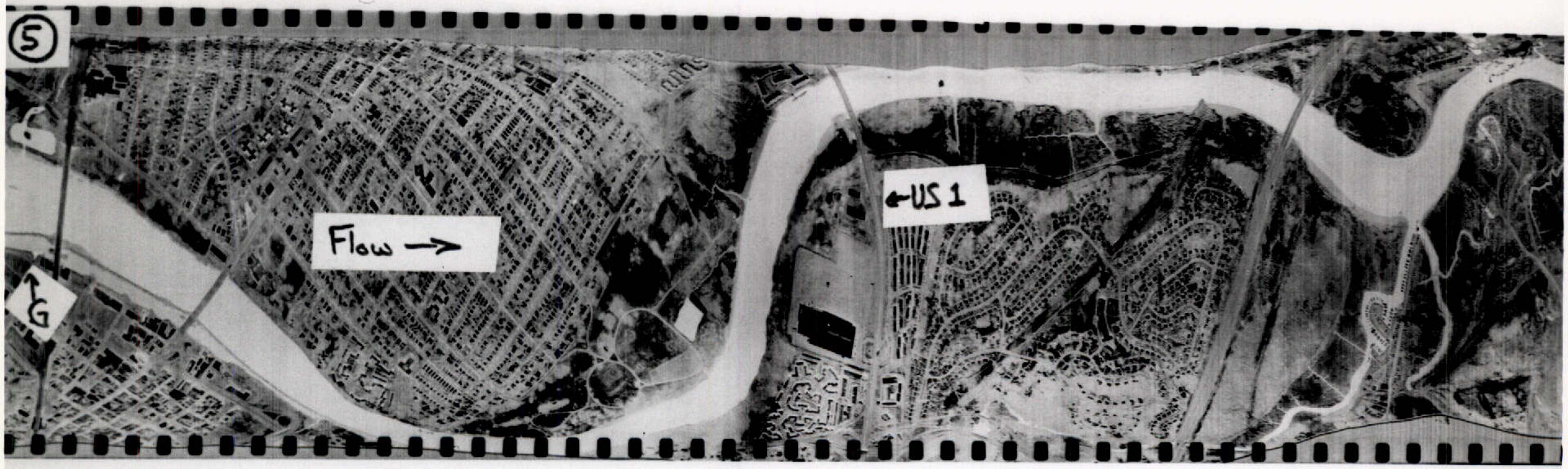
Figure 3.--Infrared imagery collected on November 6, 1968 at NASA Test Site 161, Manville (1) to East Brunswick (5).



FLIGHT LINE 1



FLIGHT LINE 1 - Cont.



Other thermal contrasts can be seen in the river between points D and F. The darker (colder) areas are due to the influence of colder ground temperatures in areas of shallow water (low tide). Also, note the thermal variations in the tidal areas below point G, due to variations in tidal or wind currents.

In an effort to further enhance the thermal contrast due to waste-water discharge and channel characteristics, the imagery illustrated on figure 3 was further processed by using an electronic density slicing instrument. With this instrument four image scenes were displayed individually on a 24-inch television screen and false colors are assigned electronically into a maximum of 32 selected density ranges. In effect, this enlarged and enhanced the particular part of the image being studied. A color photograph of each of the four television images is shown on figure 4.

The photographs of sites A and C are enlargements of the imagery (fig. 3) in the vicinity of two industrial waste-water discharge points. Water areas of warmest temperatures were assigned yellow, with the lightest shade the warmest; the next lower range of temperatures, shades of blue; and then green. Thus, green shades in the water areas, primarily along the canal shores at site C, represent the coldest water temperatures. As was mentioned previously, the effluent at site A is split. One part (upper right) is dispersed through a pipe laid in a small weir across the streambed. The mixing pattern of this dispersal is readily seen on this photograph. The second and minor part (upper center) discharges directly into the river and can be seen to entrain along the shore. The enlargement and assignment of false coloration enhances the definition of the thermal contrasts and dispersion of these discharges.

The photograph at site C also shows an industrial waste-water discharge. Close study of the area of discharge on the photograph suggests the possibility of at least three and possibly four individual points of discharge along the shoreline.

A photograph of the colored enlargement of the imagery in the vicinity of sites D and H is used to show some of the thermal variations due to channel characteristics. The effect of a dam ("v"-shaped line across channel at left side of photograph) is shown at site H. Water is entrained to the south (lower) side of the channel during low flows (such as those observed during the November 1968 flight). Discharge over the dam appears to mix the cooler upstream surface water layer (blue) with the warmer deep water, as evidenced by the warmer area (yellow) downstream from the dam. The upstream surface cooling was probably due to a combination of convective (ambient cold air temperature) and radiant heat losses. Note also the rapidity of cross-channel dispersion of waters below the dam. Also note that below the river crossing (I-287 bridge) the water apparently cools rapidly.

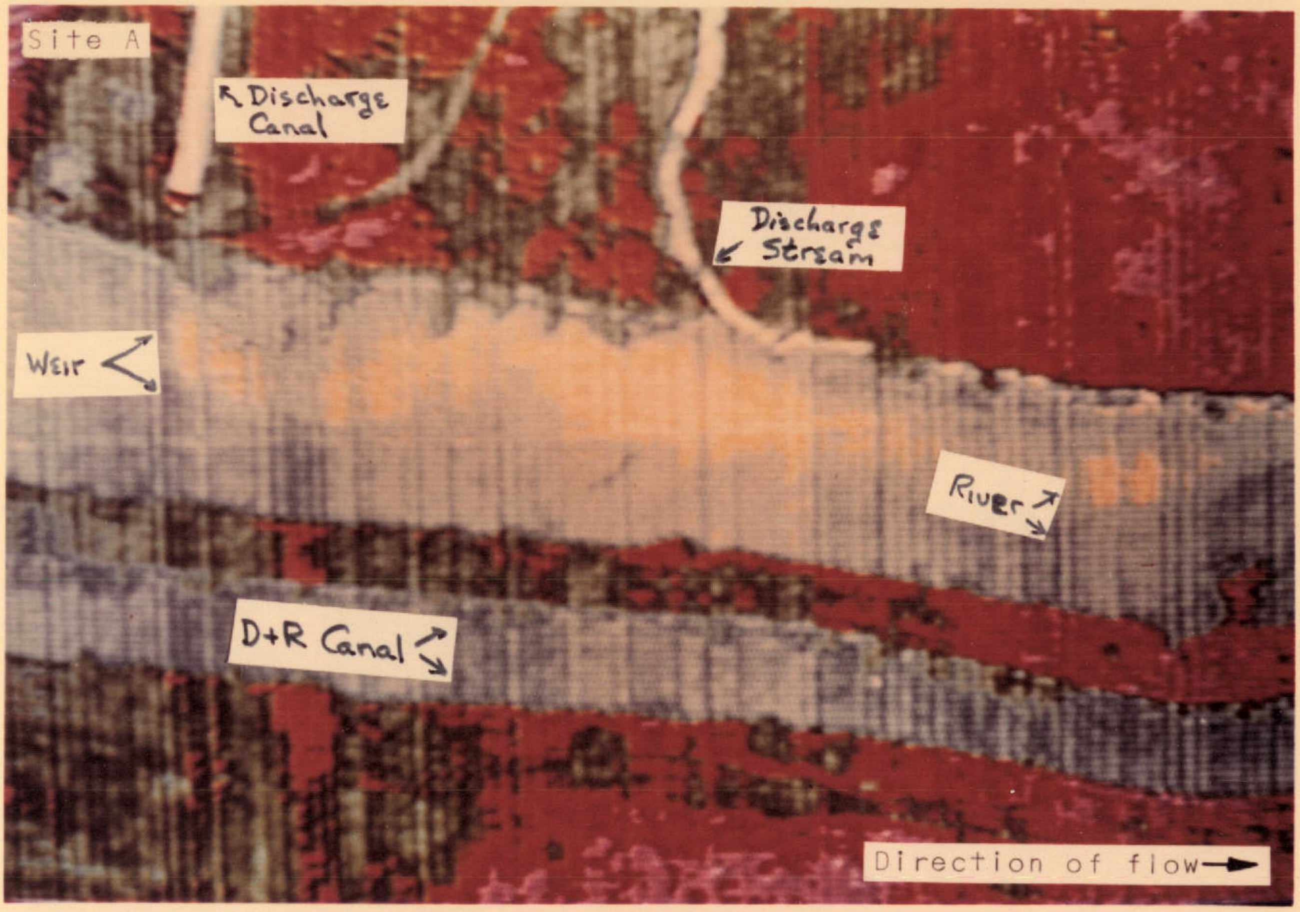


Figure 4.--Color photographs of imagery enlargements using a density slicing instrument. Site designations refer to locations on figure 3.

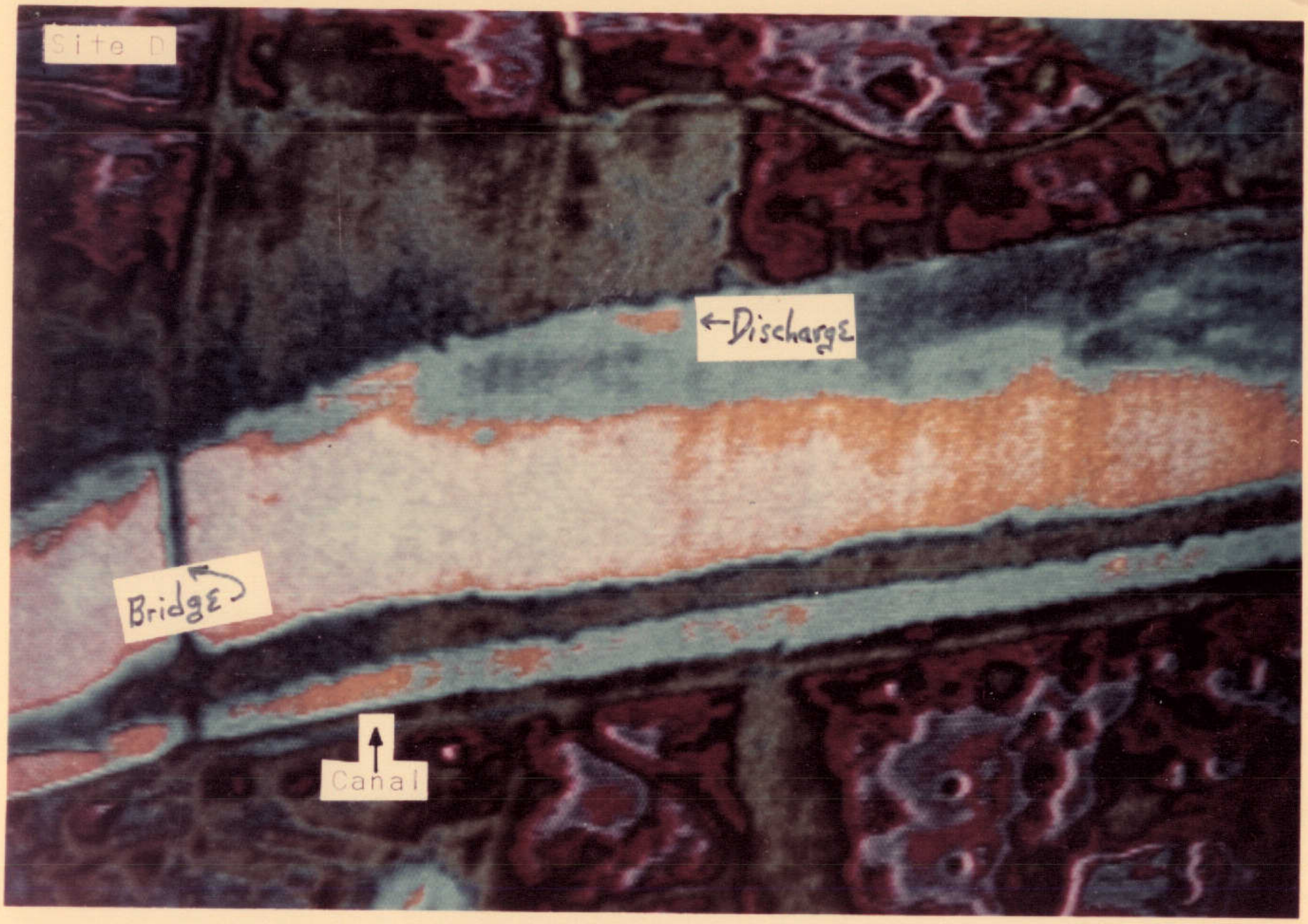
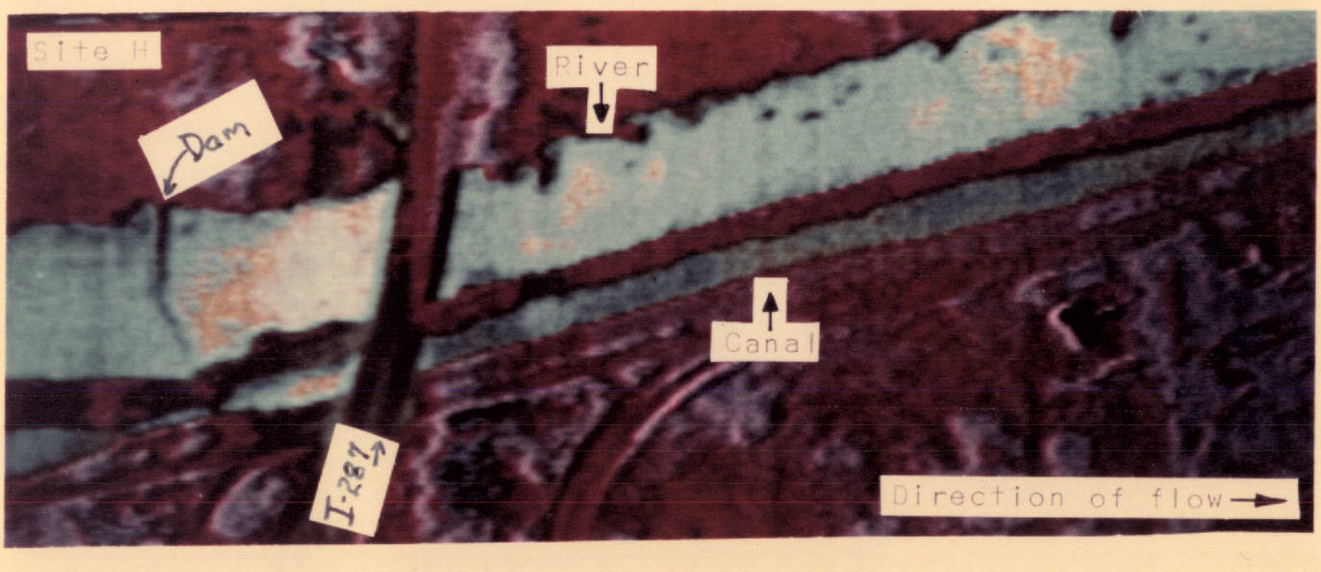


Figure 4.--Color photographs of imagery enlargements using a density slicing instrument. Site designations refer to locations on figure 3.



This is probably not an accurate observation, but related to the inability of the automatic gain control on the thermal imager to rapidly compensate for the colder bridge temperatures. A canal lock directly adjacent to the dam can be seen to produce a similar break in the thermal character of the surface layer.

The photograph of the area in the vicinity of site D indicates that the shallow water (mud banks) in the channel are relatively cold (blue).

SUMMARY

This discussion regarding the hydrodynamics of a river environment is, at most, qualitative. However, remote-sensing data collected at this site show:

1. industrial and municipal waste-water discharges into the mainstream and canal;

2. cross-channel variations in thermal characteristics due to waste-water discharge, channel characteristics, and tidal currents;

3. the influence of streamflow rates on the dispersion of waste waters;

4. patterns and distribution of ice cover; and

5. the movement of sediment loads.

Also, it has been shown that the use of density slicing can greatly facilitate the interpretation of the thermal IR imagery. For example, an investigator (after a short training period) can easily enlarge and display a part of the image that may have subtile density variations recorded on the film that cannot be detected by the human eye. Temperature ranges can be assigned to the false color patterns by correlating the colors of the pattern with measured temperatures at ground level to estimate synoptic quantitative surface temperatures. The major advantages to the investigator are the rapidity in which an image can be enlarged; the ability of the equipment to detect and display discrete density levels; and the clarity of density definition made possible by false coloration, without the use of a densitometer or electronic analysis of imager output.

REFERENCES

Bratton, R. D., 1968, Earth resources aircraft program, Mission summary report, Mission 65: National Aeronautics and Space Administration, 46 p.

Eaton, W. A., 1969, Earth resources aircraft program, Mission summary report, Mission 82: National Aeronautics and Space Administration, 35 p.

Faust, S. D., Stutz, H., Aly, O. M., and Anderson, P. W., 1970, Recovery, separation, and identification of phenolic compounds from polluted waters. Part 1 - Occurrence and distribution of phenolic compounds in the surface and ground waters of New Jersey: U.S. Geol. Survey Open-file report, 48 p.

Laskowski, S. L., 1970, Statistical summaries of New Jersey streamflow records: N.J. Div. of Water Policy and Supply, Water Resources Circ. 23, 264 p.